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Sea Otter Predation on Dungeness Crabs in Glacier Bay, Alaska

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Abstract

Sea otter (*Enhydra lutris*) populations are increasing and expanding into areas of Southeast Alaska where Dungeness crabs (*Cancer magister*) are commercially harvested. Although sea otters are known to feed on Dungeness crabs, their effects upon crab demography have not been quantified. We censused Dungeness crabs in adjacent areas within Glacier Bay National Park and Preserve with and without sea otters in April 1993, 1994, and 1995 to investigate the effects of sea otter predation. Two different crab survey techniques were used. Commercial crab pots with sealed escape rings and baited similarly were soaked for 24 hours to measure CPUE in 0-25 m depths. A minimum of 50 pots was used for each site; 25 additional pots were used in 1994 and 1995 to sample crabs to 95 m depths. Divers censused crabs along belt transects (2 m × 100 m) laid perpendicular to shore from 0 m depth to 18 m; 15 transects were surveyed at each site on each date. Sea otter numbers were estimated from aerial surveys and boat observers. Prey types and feeding rates of sea otters were made from telescopic observations. In Outer Dundas Bay, where 46, 39, and 40 sea otters were present in 1993, 1994, and 1995 respectively, CPUE of Dungeness crabs in pots was 0.04, 0.04, and 0.2 crabs/day, respectively, at depths to 25 m, but was higher (4.0 crabs per day) at deeper depths (95 m). Only two Dungeness crabs were observed in 45 diver transects surveyed during three years in Outer Dundas Bay, however Dungeness crabs were a common prey item (15%) of sea otters. Approximately 16 km N in Inner Dundas Bay, where no sea otters were observed any year, CPUE of Dungeness in pots was 2.7, 1.8, and 2.5 crabs per day for 1993, 1994, and 1995, respectively. Adult crab density estimated from diver transects was 236, 78, and 50 crabs/ha in 1993, 1994, and 1995, respectively. Significantly lower crab densities and CPUE occurred in the site occupied by sea otters. Our data imply that sea otter predation decreases Dungeness crab abundance and may induce movement of crabs to greater depths. A depth refuge for crabs from sea otter predation may vary with local bathymetry.

Introduction

Since their reintroduction to southeast Alaska beginning in 1965 (Burris and McKnight 1973), the population of sea otters (*Enhydra lutris*) has been increasing and their range expanding into inside waters, where a majority of the southeastern Alaska commercial Dungeness crab (*Cancer magister*) harvest occurs. Sea otters were eliminated from southeast Alaska by the fur trade before 1900. Between 1965 and 1968, 402 animals were translocated to six sites on the outer Alaskan coast (Burris and McKnight 1973, Jameson et al. 1982). The population remained low until 1987 when it began a period of rapid growth (Pitcher and Imamura 1990).

Sea otters are known to have a diverse diet (Doroff and DeGange 1994, Ebert 1968), but in most parts of their Alaskan range sea otters have been documented as feeding primarily on sea urchins (Estes and Duggins 1995) and bivalves (Kvitek and Oliver 1992, Kvitek et al. 1992). Although sea otters have been reported to prey heavily on Dungeness crabs in Prince William Sound, Alaska (Garshelis 1983, Garshelis et al. 1986), the effects of their predation upon crab demography have not been quantified.

The Dungeness crab supports a substantial commercial and sport fishery in southeastern Alaska. In 1992, 243 commercial crabbers held permits to fish in Southeast Alaska, harvesting over 3 million pounds of crab. With the limited-entry program for the Dungeness fishery in 1997, 308 crabbers will be eligible for permits (S. Shirley, Commercial Fisheries Entry Commission, pers. comm.). If sea otter predation on Dungeness crabs in southeastern Alaska is of the same magnitude as it was in Prince William Sound, an average of 14 crabs per adult sea otter per day (Garshelis et al. 1986), the effects upon the commercial fishery could be devastating. If the estimated population of 10,000 sea otters consumed only Dungeness crabs, the 1995 commercial harvest of Dungeness crabs could be consumed in less than two weeks. We expect that such calculations are absurd, but they do serve to emphasize the magnitude of the potential problem.

Beginning in April 1992 we conducted surveys of Dungeness crab populations twice annually at locations in or adjacent to Glacier Bay National Park and Preserve as part of a long-term study (MADS, Multi-Agency Dungeness Study) implemented to study the effects of commercial crabbing upon several attributes of Dungeness crab biology (Leder 1994, Leder and Shirley 1995, O'Clair et al. 1995, O'Clair et al. 1996, Schultz 1996, Schultz and Shirley 1996, Schultz and Shirley in press). The five study sites, Gustavus Flats, North Beardslee Islands, South Beardslee Islands, Berg Bay, and Bartlett Cove (Figure 1), at the time had no or a low historical incidence of sea otters. With the advent of sea otter sightings and the concern of additional sea otters moving into our study areas, two additional sites, Outer and Inner Dundas Bay, were added in April 1993 (Figure 1). Outer Dundas Bay has been populated by sea otters since at least 1989 (Pitcher and Imamura 1989) while sea otters have not been observed in the upper reaches of Dundas Bay, approximately 16 km NW, hereafter referred to as Inner Dundas Bay.

The objectives of this study were to: (1) compare CPUE and abundance of Dungeness crabs in adjacent areas with and without sea otters and to compare to values collected with similar methodology in 1989 by the Alaska Department of Fish and Game (Pitcher and Imamura, 1990); (2) compare depth distribution of Dungeness crabs in areas with and without sea otters; and (3) examine the diet of sea otters in southeastern Alaska.

Methods

Dungeness crab abundance was assessed by two methods, commercial crab pots and scuba diver transects. At each site 50 commercial Dungeness crab pots were soaked for 24 hours: 25 pots were set in depths of 0-9 m and 25 pots were set in 10-25 m. At Outer Dundas Bay, which has greater depths available, an additional 25 pots were set at depths of 64-95 m in 1994 and 1995. The pots were baited similarly with a mixture of herring and squid and hanging bait of salmon and cod. The escape rings of all pots were sealed in order to retain small crabs. All pots were numbered and the depth and location of each pot was recorded. Catch per unit effort (CPUE) was determined per pot standardized to a 24 h soak period.

Crabs were identified by sex and females were classified as ovigerous (with an egg clutch under the abdominal flat) or nonovigerous. Carapace width was measured with vernier calipers to the nearest millimeter immediately anterior to the tenth anterolateral spines. Carapace condition was categorized as soft (recently molted), new (sharp spines and bright colors), old (dull spines and colors, with some fouling organisms) and very old (dull spines, heavy fouling, larger barnacles and often with

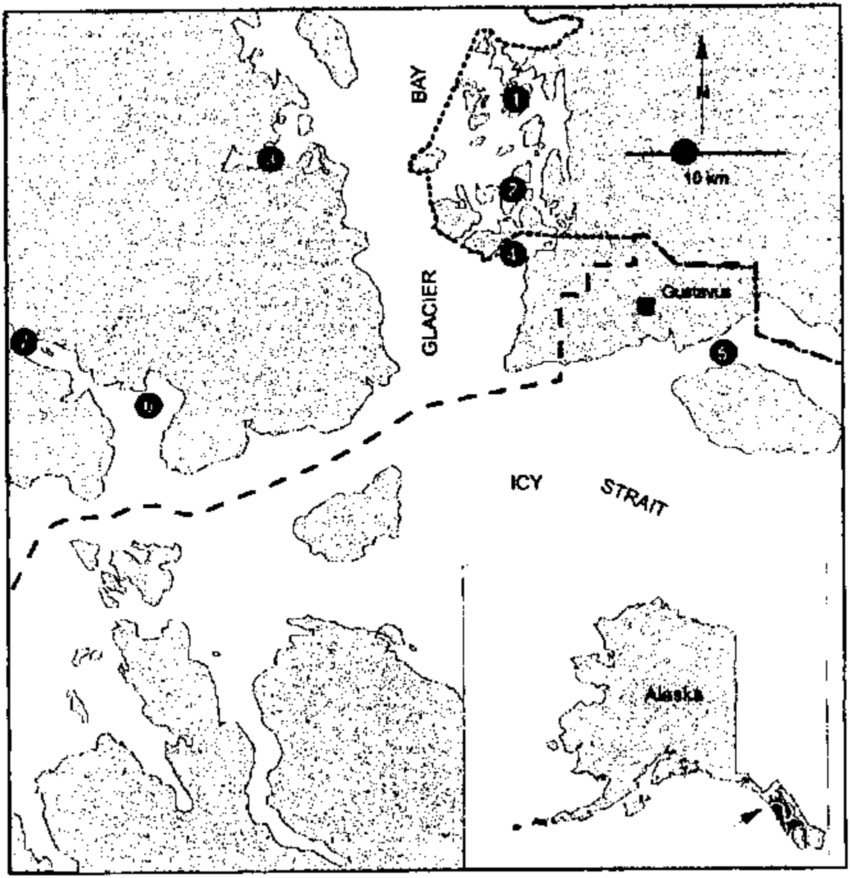

Figure 1. Study locations in and adjacent to Glacier Bay National Park and Preserve. Numbered locations are: (1) North Beardslee Islands, (2) South Beardslee Islands, (3) Berg Bay, (4) Bartlett Cove, (5) Gustavus Flats, (6) Outer Dundas Bay, (7) Inner Dundas Bay.

macroalgae) (Shirley and Shirley 1989). Carapace and appendage damage and evidence of regeneration of appendages was also recorded. More detail of the variables measured and techniques are provided by Leder (1994) and Schultz (1996).

Divers using scuba gear censused crabs along belt transects (2 × 100 m) perpendicular to shore from the shallow subtidal (0 m, MLLW) to 18 m depth or until the end of the 100 m transect, whichever came first (O'Clair et al. 1995, O'Clair et al. 1996). Fifteen randomly placed transects located within the area where pots had been located were conducted at each study site. Crab number, sex, reproductive condition, and number of legal-sized males were counted by 10 m quadrats along each transect.

Sea otter abundance was determined by aerial and small boat surveys. Sea otter diet was assessed by telescopic observation by trained observers.

Crab and sea otter surveys were conducted at approximately the same time in the third week of April in 1993-1995. Diver transects were conducted concurrently with the pot survey in 1993, but followed by 1-5 days in 1994 and 1995. All values are reported as mean ± standard error.

Results

In Outer Dundas Bay, CPUE was uniformly low in pots at 0-25 m depth, being 0.04 ± 0.03 crabs per pot per day in both 1993 and 1994 and 0.2 ± 0.1 in 1995 (Figure 2). At the deeper depths, CPUE increased, from 0.4 ± 0.2 crabs per pot per day for pots in 20-60 m depth in both 1994 and 1995, and to 3.9 ± 0.8 and 4.0 ± 1.0 crabs per pot per day for pots from 60-90 m depth in 1994 and 1995, respectively (Figure 3). In sharp contrast, Inner Dundas Bay had CPUEs of 2.7 ± 0.4, 1.8 ± 0.3, and 2.5 ± 0.5 crabs in 1993, 1994, and 1995, respectively. The bathymetry of Inner Dundas Bay is shallow, so that no pots can be set at deeper depths for comparison; however, the CPUE of crabs in pots from 0-10 m was twice that of pots from 10-20 m depth.

The low CPUE of crabs in pots from Outer Dundas renders consideration of sex ratio of questionable value. Two males were caught in pots at 0-25 m depth in Outer Dundas in both 1993 and 1994, while 8 males were collected in 1995 from the same depths. In the 25 pots set deeper (25-95 m), 40 males and 1 female were collected in 1994, but 42 males, 1 nonovigerous and 3 ovigerous females were collected in 1995. In Inner Dundas Bay, 104 males and 30 nonovigerous females were collected in 1993; 59 males and 24 nonovigerous females were collected in 1994; and 113 males, 8 nonovigerous, and 5 ovigerous females were collected in 1995.

Crab abundance in diver transects followed similar trends as the CPUE reported for pots. No crabs were found in a total of 30 transects

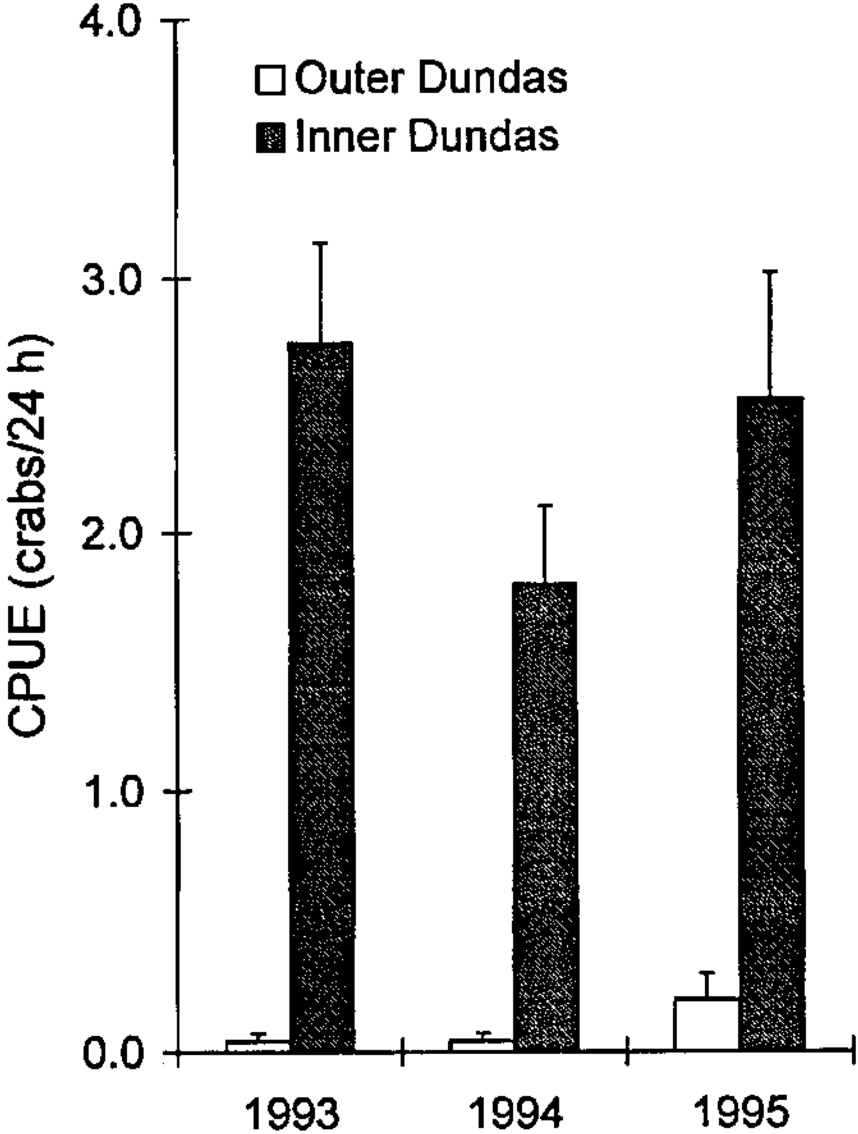

Figure 2. Mean catch per unit effort (CPUE) of crabs/24 h in commercial crab pots (n = 50 pots) in Outer and Inner Dundas Bay from 1993-1995. Vertical bars represent one standard error.

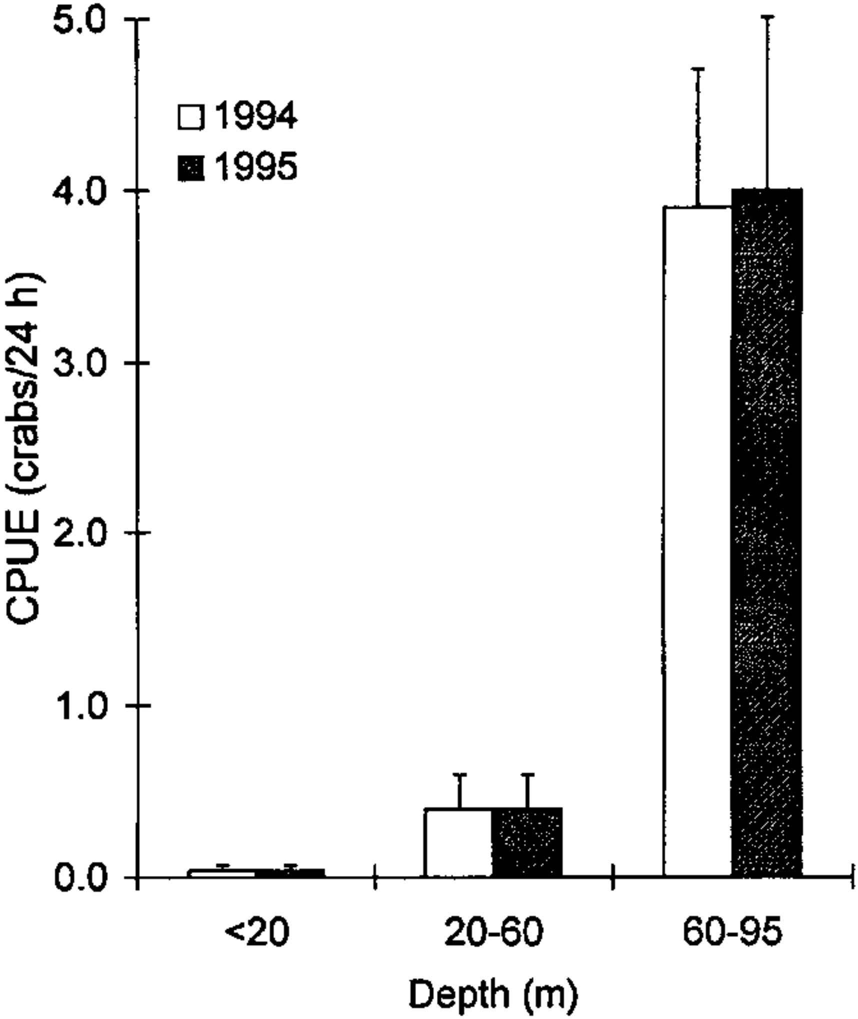

Figure 3. Mean CPUE of crabs/24 h in commercial crab pots by depth in Outer Dundas Bay in 1994 and 1995. Means are for 50 pots at depths < 20 m, 15 pots for 20-60 m depth, and 10 pots for 60-95 m depth.

conducted in 1993 and 1994 and only 2 in 15 transects in 1995 in Outer Dundas Bay, in contrast to an abundance 236 ± 88.7, 78.1 ± 30.4 and 50 ± 22.9 crabs per hectare in 1993, 1994, and 1995, respectively, in Inner Dundas Bay (Figure 4).

Numbers of sea otters in Outer Dundas Bay remained relatively constant, with minimum counts during aerial surveys being 46 in 1993, 39 in 1994, and 40 in 1995.

Prey composition of sea otters in Outer Dundas Bay was 65% bivalves (*Saxidomus* sp., *Macoma* sp. and *Prototheca* sp.), 15% crustaceans (*Cancer magister* and *Chionoecetes bairdi*) and 20% other (green sea urchins, sponge, sea cucumbers, octopus, sea stars, and snails). Of the crustaceans consumed, 95% were Dungeness crabs (Figure 5). The above values represent an overall average of prey composition. Three sites were sampled within Outer Dundas Bay for prey composition of sea otter diets and the proportions varied among the sites as follows: (1) 26% bivalves, 46% crustacean, 28% other; (2) 96% bivalves, 1% crustacean, 3% other; and (3) 58% bivalves, 7% crustacean, 35% other.

Discussion

Dungeness crabs have large spatial and temporal variations in abundance (Botsford 1986, Johnson et al. 1986) that complicate interpretations of the impact of sea otter predation on crab abundance. Also, different spatial scales of dispersion (i.e., degree of aggregation) for different sex and life history stages of Dungeness crabs have been reported to vary with location within Glacier Bay (O'Clair et al. 1996). Interannual variations in the CPUE of different sex and life history stages of Dungeness crabs in five different bays within and adjacent to Glacier Bay were documented by Leder (1994) and Schultz (1996). In addition, the harvest of the commercial crab fishery should be expected to affect the abundance of crabs. The total harvest varies not only in response to interannual variations in abundance of crabs, but also in response to market demand.

The results of our survey suggest that sea otter predation affects the abundance and bathymetric distribution of Dungeness crab. The lack of multiple, paired sites and circumstantial nature of our data limit the inferences which can be derived; however, strong patterns are evident. In the presence of sea otter predation in Outer Dundas Bay, the CPUE of crabs was not significantly different from zero. Similarly, scuba divers found only 2 crabs in 45 scuba diver transects during 1993-1995 in the area where sea otters were present. In the upper reaches of the same bay (Inner Dundas) where otters are not observed or rarely present, CPUE varied from 1.8 to 2.7 crabs per pot during 1993-1995. The abundance of crabs in scuba diver transects declined steadily from 236, to 78, then to 50 crabs per hectare in 1993, 1994, and 1995, respectively, in Inner Dundas Bay. We do not know if the decline is related

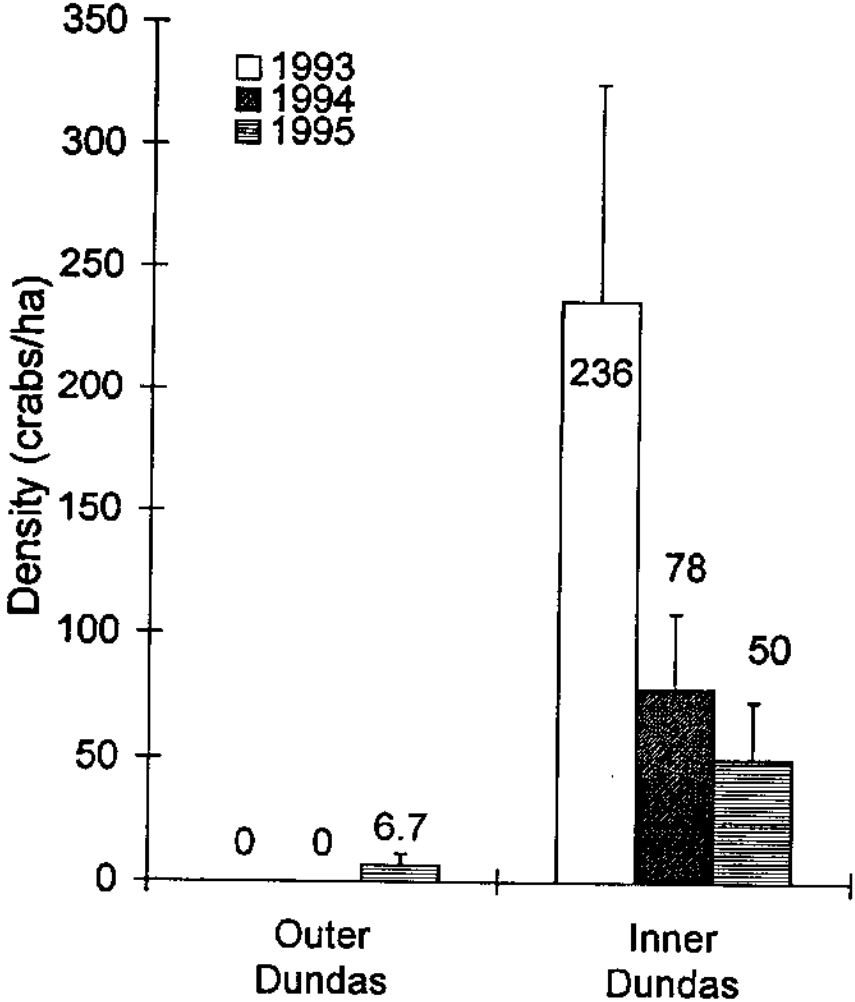

Figure 4. Mean Dungeness density in diver transects (n = 15 diver transects per value) in Inner and Outer Dundas Bay in 1993-1995. Transects terminate at 18 m depth or shallower.

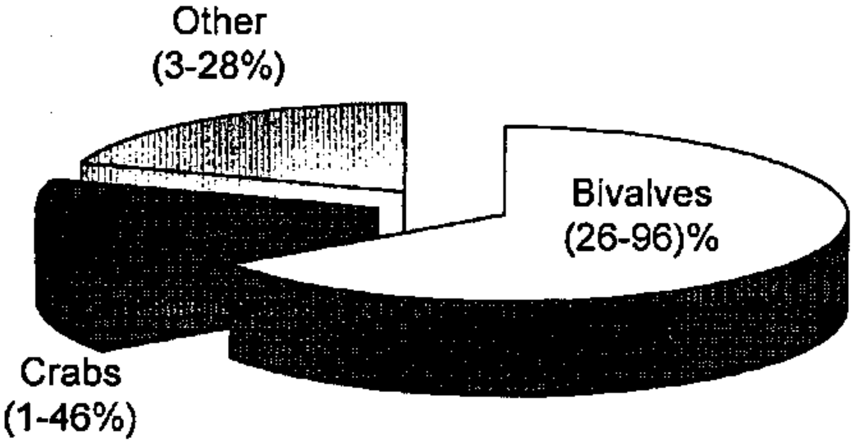

Figure 5. Mean composition of sea otter diet in Outer Dundas Bay in 1993. Values are averaged from telescopic observations at three locations. Other includes sea urchins, sea cucumbers, sea stars, snails, sponge, octopus.

to predation or resulting from long-term trends in population abundance.

The CPUEs that we report for both Outer and Inner Dundas Bay are sharp declines from the 1989 CPUE in Dundas Bay reported by Pitcher and Imamura (1990) of 10.49 ± 11.75 (mean ± standard deviation) crabs per pot per day. Although our crab pots were baited and set for 24 h in an identical manner as those of Pitcher and Imamura (1990), the values are not strictly comparable because crab pot locations and depths were not the same.

Sea otters were first reported in Dundas Bay by Pitcher and Imamura (1990). The CPUE they reported for Dundas Bay (10.49 crabs per pot per day) was one of the higher values they reported for areas along Icy Strait that did not have sea otters. It is likely that sea otters had not yet significantly decreased the numbers of Dungeness crabs in Dundas Bay at the time of their sampling, as the CPUE they reported for Dundas Bay in 1989 differs little from our overall CPUE from 5 bays within Glacier Bay during 1992-1995 of 9.4 crabs per pot per day (unpublished data). Pitcher and Imamura (1990) hypothesized that the low CPUE of Dungeness crabs in two other bays along Icy Strait, Idaho Inlet and Mud Bay, were likely the result of sea otter predation and predicted that substantial numbers of sea otters would populate Dundas Bay within three years and have a negative effect on Dungeness crab abundance. Our data corroborate their hypotheses and prediction.

A strong aspect of our study is our observations of sea otter diet in our crab study area. Sea otters were actively feeding on Dungeness crabs even though our divers could not find them in transects and few were collected in our crab pots. On average, 15% of the sea otter diet in Dundas Bay was crabs, of which 95% were Dungeness crabs. If crabs had been more abundant within Outer Dundas Bay, predation rates might have been considerably higher. Our sea otter feeding rates on crabs should be considered conservative, as some sea otters have been reported to feed nocturnally when Dungeness crabs are more active (Ralls et al. 1995), when telescopic observation of diet is not possible.

The increase in CPUE of Dungeness crabs with depth in Outer Dundas Bay has several implications. One inference is that depth may be a refuge from predation for the crabs. Although Dungeness crabs have been reported to 179 m depth (Hart 1982), they are generally found in nearshore areas and most of the commercial fishery in Alaskan waters occurs in less than 25 m depth (unpublished observations). In most of our other study locations in or near Glacier Bay, bathymetry prevented us from setting crab pots in deeper depths; however, in the South Beardslee Islands, CPUE of Dungeness crabs decreased with increasing depth to 60 m in 1995 and 1996 (unpublished observations). The diving depth of sea otters can exceed 100 m (Newby 1975) but most dives are in shallow water (VanBlaircom and Estes 1988, Kvitek et al. 1992, Ralls et al. 1995). As an interesting aside, we found Dungeness crabs in commercial Tanner crab pots at 183 m depth in Outer Dundas Bay (unpublished observations). In our April 1996 sampling in Outer Dundas Bay, the largest number of Dungeness crabs collected were in our deepest pot at 123 m. Another consideration of a possible depth refuge is that predation by sea otters may be biased towards certain sex and life history stages of Dungeness crabs. Ovigerous females tend to bury in dense aggregations, often in shallow water (O'Clair et al. 1996, Schultz 1996), perhaps rendering them more susceptible to sea otter predation. O'Clair et al. (1995) did find seasonal differences in sex distribution of Dungeness, but not significant differences in depth distribution between ovigerous and nonovigerous Dungeness crabs. However, the depth range studied was restricted to < 18 m. At our deep set of pots in Outer Dundas in 1995, 3 of 4 females collected were ovigerous.

Whether Dungeness crabs move to deeper depths in response to sea otter predation, or have substantial abundance at depth are questions that would have significant implications to the commercial fishery and to management agencies. The impact of sea otter predation may manifest itself only in movements of the crab populations, or conversely, a deep-dwelling population of Dungeness crabs may serve as a buffer against overexploitation.

The colonization of the inside waters of southeastern Alaska by sea otters has been relatively slow in comparison to their expansion along the oceanic coast. Similarly, sea otters do not seem to frequent some embayments such as Inner Dundas, even though sea otters are common in adjacent waters. Kvitek and Oliver (1992) suggested that high levels of paralytic shellfish toxins may protect some clam populations and limit the distribution of sea otters in some areas.

Most of the considerations of the effects of sea otter predation has been that of direct effects upon a commercially harvested species, Dungeness crab. More profound community level effects have been proposed (Kvitek et al. 1992). Sea otters reduce the size and abundance of their prey, and foraging-related disturbance and facilitation may enhance the abundance of other species. Removal of a large generalist predator such as the Dungeness crab may greatly affect the densities of its prey and competitors. Foraging pits created by the sea otters may facilitate predation by sea stars such *Pycnopodia helianthoides* which appear attracted to sites of sea otter activity (Kvitek et al. 1992). We have observed unusually high densities of *Pycnopodia helianthoides* in Outer Dundas Bay. High numbers of bivalve shells discarded by foraging sea otters increases the hard substratum available to benthic sessile species (Kvitek et al. 1992). Many of these community level changes could have impacts on possible later recolonization by Dungeness crabs. Additional community level studies of the impact of sea otter predation are needed.

We suggest that the long-term impact of sea otters on Dungeness populations may depend upon local bathymetry and recruitment source. In areas where crab recruitment is exogenous or where the bathymetry offers a refuge from predation, sea otter predation may not be as deleterious. Clearly additional study of this difficult but important topic is warranted. Long-term surveys of locations where sex and life history dispersion patterns of Dungeness crabs are known before, during, and after sea otter invasion may be one method of addressing the challenge.

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